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NAME AND LOCATION: Alan Strahler, Boston University

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### ABSTRACT -- KEY POINTS

#### BRDF/Albedo

Version 1 software was delivered in early August and accepted by the software test and integration team, a major milestone. Version 4.0 of the ATBD was completed and delivered to the project in early December. A large international BRDF workshop was held in Beijing, China, in September. A paper outlining the MODIS BRDF/albedo product was accepted for publication in the Journal of Geophysical Research, a paper on validation of the BRDF models to be used by MODIS was submitted to Remote Sensing of the Environment, as was a paper applying successfully the MODIS BRDF algorithm to AVHRR data in the HAPEX-Sahel area of northern Africa. A key study of the sensitivity of atmospheric correction of reflectances to the surface BRDF was carried out. Measurements of the BRDF of three broadleaf vegetation canopies were made under laboratory conditions in Changchun, China. Agreement with the MISR validation team was reached on BRDF/albedo and MODLAND participation in AirMISR validation activities.

#### Land Cover/Land Cover Change

Versions 4.0 and 4.1 of the ATBD were delivered in December. Status and progress was reported to the Land Review Panel in December. Boston University hosted a MODLAND Land Cover Working Group Meeting in November. Algorithm development for the land cover and land cover change products continued with pre-processing and analysis of TM for Glacier National Park and AVHRR data for Central America and the Caribbean. Testing and modification of the neural net and decision tree classifiers continued on the 1-degree global NDVI dataset.

#### Administrative

We hired a replacement programmer, Dr. Crystal Schaaf, to replace the programmer who resigned unexpectedly in late August. Although she comes from the physical science side rather than the computer science side, we think she will be as productive, if not more so, than the programmer she replaces. She has good experience with our team and our mission,

having earned her PhD on BRDF related topics in 1994.

## **TASK PROGRESS**

### **BRDF/Albedo Product**

#### **BRDF/Albedo Product Version 1 Software Delivery**

Version 1 coding progressed in July and early August. The code was delivered to SDST earlier than most other codes in early August. It runs considerably faster than the beta-3 code, is more complete scientifically, produces an improved format, and adheres to the version 1 ECS- and MODIS-mandated metadata concepts. Full quality assessment is being carried out on the pixel level. Contacts with SDST continued after delivery as the code was passed through the code acceptance process, which was completed successfully. In the last 3 months of the reporting period, numerous updates were made to the code through SDST as testing progressed and the code was adapted to new requirements from ECS. The programmer hired for MODIS programming, Jim Tallent, left the project in mid-August and was replaced on October 1 by Crystal Schaaf, hired as a Research Assistant Professor due to her scientific expertise. Crystal Schaaf has a long history of prior involvement with MODIS land activities and cloud masking, and with BRDF modeling. The BRDF/Albedo product changed its code from MOD09B to MOD43 for technical reasons.

A draft quality assurance plan was developed in conjunction with a MODLAND-SDST meeting July 11-12 and adapted to the specific needs of the BRDF/albedo product in terms of metadata and SDS-level quality control. The mandatory parts of QA are still under discussion, but the product-specific QA fields have been defined for the BRDF/Albedo product.

#### **BRDF/Albedo Science Advances**

A study was carried out on the sensitivity of atmospheric correction of reflectances to the surface BRDF, on errors made in BRDF/albedo retrieval if a Lambertian assumption is used in atmospheric correction, on the improvement in these errors if the retrievals are iteratively coupled, and on the influence of diffuse skylight on the BRDF/albedo retrieval accuracies. This study is key in resolving the interdependence of the MODIS atmospheric correction and BRDF/albedo algorithms. The results confirm that BRDF effects should be taken into account in atmospheric correction (planned for MODIS, but not usual otherwise), but that there is some leeway in the exact shape of the BRDF used, allowing a loose iterative coupling to succeed. Plots are

now available allowing to assess the RMSE in retrieved directional reflectances as a function of error in the assumed albedos in atmospheric correction for MODIS and MISR angular sampling distributions, several different land cover types, and different values of the optical depth. A manuscript has been prepared.

A second study was carried out expanding and completing an earlier study on the sensitivity of BRDF/albedo retrievals to changes in angular sampling for different land cover types (produced using Myneni's 3-dimensional discrete ordinates radiative transfer code) and wave bands. Angular sampling was studied as a function of latitude and time of year for combined MODIS and MISR data. The MODIS designated semiempirical Ambrals BRDF model was tested as well as the modified Walthall and the MISR designated RPV BRDF model. Results show that the Ambrals BRDF model produces good results and is a well justified choice for MODIS BRDF/albedo processing. The RPV model behaves equally well, but the Walthall model shows some problems. Albedo can be retrieved to better than 10 percent relative in most cases, often a lot better, both at the mean sun angle of observation and extrapolated to angles where no observations were made, which is a rather severe test. The same holds for nadir reflectance. A manuscript has been prepared.

AVHRR data acquired over several months over the HAPEX-Sahel area in Niger, Africa, were inverted using the MODIS BRDF/albedo algorithm. Besides demonstrating the feasibility of the algorithm using real data, the most interesting results of this study were the observation that Ambrals BRDF model kernel selection shows a good consistency over time, and that the model parameters show interesting temporal trajectories that may be interpretable in terms of biophysical changes during the year.

One week in September was spent in the Solar Simulation Laboratory at Changchun, China, operated by the Chinese Academy of Science. This unique facility allows the rapid measurement of the BRDF of vegetation under laboratory conditions. The BRDFs of three different broadleaf plants were acquired, one interesting result being that details of plant canopy structure could be correlated with local effects in the observed BRDFs. The data acquired will be used for BRDF model validation.

#### BRDF/Albedo Product ATBD Version 4.0 Delivered

A new Algorithm Technical Basis Document was delivery (version 4.0) in early December. The main body of text amounts to 80 pages, followed by detailed responses to 2 previous rounds of product reviews, and an appendix containing all scientific material generated in support of the

MODIS BRDF/albedo algorithm, bringing the total length of the document to 250 pages. This document allows a very detailed assessment of the status of BRDF/albedo inversions for MODIS. A mail review of this ATBD is still under way.

#### BRDF/Albedo Product Validation

Wolfgang Wanner attended the MISR science team meeting in Pasadena, August 12-14, on behalf of the BRDF/albedo team and MODLAND. There are many areas with possible synergy between MODIS and MISR. Besides establishing the contacts required for working on the data flow from MISR into the MODIS production chain, the main benefit of this trip was to have proposed MODIS BRDF/albedo participation in the several AirMISR campaigns in 1997 and a coordination of flight locations and times. Validation needs between MODLAND and MISR-land are very similar, making joint field experiments most productive. AirMISR has properties that will make it an instrument we'd prefer to use rather than ASAS, most notably it will cover a larger area on the ground (8 by 10 km) and have a somewhat lower pixel resolution (10 m).

MODIS BRDF/albedo personnel will likely participate in the AirMISR calibration campaign in May/June 1997 at Lunar Lake and in the AirMISR campaign in late August over Rock Springs, PA. MODLAND-designated AirMISR flights are currently being negotiated and seem likely in addition. A ground component to go with these flights is being developed and will focus on the spatial characteristics of albedo, probably through transects. Details will emerge in early 1997.

#### International BRDF workshop

From September 16-18 the first international workshop on multiangular remote sensing was held in Beijing, China. Most of the BRDF scientific community worldwide attended, allowing for very interesting discussions on the current state of the art. The MODIS BRDF/albedo plans and sensitivity studies were presented in two separate talks and met with the approval of the workshop. A spirited discussion of the future direction of BRDF research concluded the proceedings. Papers given at the work shop will be published in a special issue of a Chinese remote sensing journal.

#### Land Cover/Land Cover Change

During this reporting period, we focused primarily on responding to the SWAMP EOS-AM1 Land Workshop review and incorporating changes into a revised ATBD which was delivered in December 1996. The MODIS Science Team Review was conducted in December. We continued to concentrate on

the validation plan, test site issues and algorithm development for land cover classification. We continued our work with advanced technology (AT) classifiers: neural nets, decision trees and adaptive classifiers.

### Outreach and Coordination

Boston University hosted a Land Cover Workshop in November. The purpose of the workshop was to continue progress on test site, validation and classification issues, and to expand outreach to user communities in landscape ecology and global modeling. We also met with the University of Maryland Land Cover Team to coordinate MODLAND Land Cover activities especially in the areas of test site development and processing continuity.

### Test Sites

The lack of an adequate test site network and IMS is a significant problem which greatly impedes algorithm testing and product validation for land cover (and other MODLAND products). These data are needed for training, validation and accuracy assessment. We began developing a global test site data metadata database in December to be used for coordinating MODLAND test site activities and for targeting ancillary data (TM, ASTER, LEWIS etc.) acquisition.

### Test Site Activities

Test site activity continued in Arizona, Walnut Gulch and BOREAS, and analysis was initiated at Glacier National Park and Central America and the Caribbean.

- o Central America and the Caribbean: We began compiling and pre-processing AVHRR and ancillary data for this regional megasite test site.
- o Glacier National Park: We continued algorithm testing for TM data for Glacier National Park with the Snow/Ice Team (Dorothy Hall).
- o SNOW/ICE-Landcover New England Winter 97 Field Campaign: We continued development of a joint SNOW/ICE-Landcover New England Winter 97 Field Campaign at a megasite which includes Sleepers River, Vermont and the Hubbard Brook LTER in New Hampshire and Harvard Forest LTER in Massachusetts.
- o Global 1-degree data: We continued testing and modification of the neural net and decision tree classifiers for use with the 1-degree

global NDVI dataset.

- o Walnut Gulch/Arizona: Efforts continued in the analysis of neural nets, decision tree classifiers and feature selection techniques using the simulated MODIS data.

#### Algorithm Development and Testing

- o Neural Nets: We continued research on neural net classifiers especially their application to the global 1-degree NDVI land cover data and snow/ice/land cover discrimination using the Glacier National Park TM and SNOPMAP dataset. Pertinent issues include the use of limited training and validation (accuracy assessment) data, and geographical organization of the multitemporal data ie. stratification into latitude or hemispheric regions.
- o Decision Tree Classifiers: We have continued development and testing of multivariate decision trees for feature selection and classification.

#### Algorithm Coding and SDST Issues

We developed and delivered the land cover 32-day and quarterly V1 code in mid-July. The V1 software accepted by CM and forwarded to integration staff on 10/09/96. VI software was built on TLMCF on 11/04/96. We continue to develop the Climate Modeler's Grid code.

#### Participation in MODIS Activities

- o IGBP-DIS Landcover Working Group Workshop at JRC, Ispra, Italy (Strahler, Muchoney); 15-17 July 1996
- o Boston University/U. Of Maryland Land Cover Coordination Meeting; U. Of Maryland, 2 October
- o Modis Science Team Meeting; 9-11 October; GSFC
- o Modland Land Cover Workshop; Boston University, 4-6 November
- o ATBD Review Panel; GSFC, 11 December
- o Boston University/U. Of Maryland Land Cover Coordination Meeting; U. of Maryland, 12 December

#### Deliveries

- o Delivered the Land Cover 32-day and quarterly V1 code deliveries; mid-July)
- o Delivered ATBD Version 4.0 (interim for Review Panel); 25 November
- o Delivered ATBD Version 4.1; 6 December

#### ANTICIPATED ACTIVITIES DURING THE NEXT QUARTER (January - March 1997)

##### BRDF/Albedo Product

- o Finalization of QA plan.
- o Baselining of Version 2 product formats.
- o Start of version 2 programming.
- o Definition of validation prototype campaign (grass PROVE) with AirMISR.
- o Investigation of land cover-BRDF relationships.
- o AVHRR BRDF inversions for South America prepared.

##### Land Cover/Land-cover Change Product

In the next quarter, work will continue on Modelers Grid coding. Work on Version 1 of the land cover code will continue. We will deliver the monthly compositing algorithm, the quarterly classification algorithm and the climate modeling grid product (spatially-degraded product at 0.5 degree). This work had been set back because of unanticipated change in our programming staff.

We will complete a Global Test Site Meta Data Database which describes, the location, type and characteristics of training, testing, calibration and validation sites used/targeted by MODLAND, EOS and other institutions and programs.

We will expand algorithm testing in Glacier National Park with the Snow/Ice Team, and test site activities in BOREAS and Central America. We will participate in the joint SNOW/ICE-Land Cover New England Winter 97 Field Campaign. In addition to the 1-degree (FASIR) and 1km testing, we will begin testing using the AVHRR Pathfinder 8km data. We will continue site activities using the 1-km NDVI dataset for the western hemisphere and especially Central America. Classification algorithm development and testing includes several neural nets, as well as decision trees.

In land cover change activities, we will begin testing of change vector and neural network change detection techniques at specific sites to complement the multitemporal nature of the land cover activities.

### Participation in MODIS Activities

- o IGBP-DIS Land Cover Working Group Meeting, Santa Barbara, 21-23 January
- o MODLAND SDST meeting, 18-19 February (tentative); focus on V2 code, QA and DIS readiness)

### Projected Deliveries

- o Climate Modeler's Grid code
- o Global Test Site Metadata Database

### PROBLEMS/CORRECTIVE ACTIONS

During this reporting period, the resignation of a part-time administrative aide created difficulties in contract administration. However, the position should be filled early in the next quarter. Other than this personnel problem, we did not encounter any significant problems requiring corrective actions beyond the everyday problems that occur in research and algorithm development.

### PUBLICATIONS

(A complete list of publications is to follow at a later date.)